Europacable Technical newsletter

FttH and Optical distribution network reliability

21 September 2022

This document is addressing Optical Fibre Distribution Network (OFDN) reliability. Widely based on international technical reports, it gives the key elements and rationale for ensuring optical networks reliability.

Executive summary:

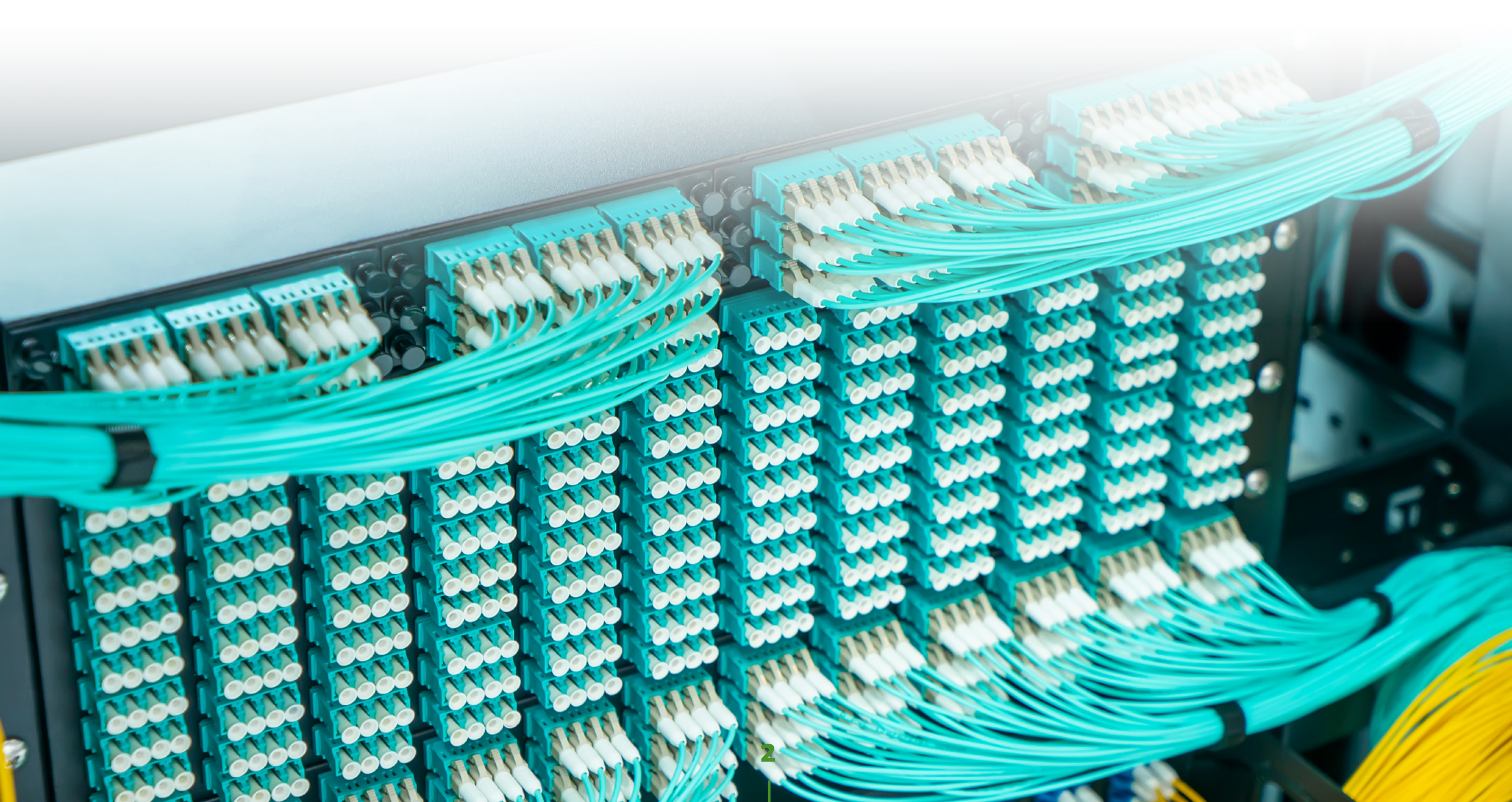
This newsletter deals with the key parameters and rationale to choose right optical fibres and optical fibre cables allowing optical distribution infrastructure long-term reliability. Special attention is paid to the optical fibres stresses and strains related to the constraints that this optical distribution network would face in its lifetime. This paper describes how to manage these stresses and strains on the optical fibres by choosing the right fibres and cables.
In 2020, Europacable published the white paper "Expected lifetime of Passive Optical Infrastructure". Readers should also refer to this document.

Optical Fibre Distribution Network (OFDN) reliability:

To ensure the robustness of optical fibre networks and to optimise their service life, the following two elements have to be considered.

- **The optical reliability:** Which ensures that the transmission of the optical signal will not deteriorate over the lifetime of the OFDN.

- **The mechanical reliability:** Which ensures that the fibres will not breakduring the lifetime of the OFDN.



Optical reliability:

Whatever the stresses to which the OFDN is exposed, the choice of the right optical fibres associated to well-designed cables are key elements.

<u>The optical Fibre type – a fundamental choice:</u>

The optical fibre type strongly determines the resilience of the network to the different events that it will experience during its lifetime. These “events” will generate bending stresses on the optical fibres (micro-bending or macro-bending).

To decrease the sensitivity to these bending stresses (macro and micro-bending), the choice of G.657.Ax optical fibres is highly relevant.
What about fibre compression?
The following chart summarizes the different sensitivity of two fibre types for an equivalent micro-bending stress induced by fibre compression (laboratory tests). The tests were performed on two fibres at the same time (G.657.A2 and G.652.D). The two fibres were laid onto sandpaper (as described in IEC TR 62221:2012 ED2) and pressure was applied to the fibres until a 0.1dB attenuation on the G.657.A2 fibre was detected. The attenuation on G.652.D fibre was then measured to compare the effect of the applied stress on both fibres under equivalent conditions. Attenuation was measured at different wavelengths.

	1500 nm	**1625 nm**	**1650 nm**
G.657.A2	+0.1 dB	+0.1 dB	+0.1 dB
G.652.D	+0.3 dB à +1 dB	+0.45 dB à +2 dB	+0.6 dB à +2.5 dB

Attenuation at different wavelengths for a micro-bending stress - Source: SYCABEL

First conclusion: Whilst standard single mode fibres, such as G.657.Ax and G.652.D, are standardised with requirements based on their macro-bending characteristics, the reaction to micro-bending stresses are very different between these fibre types. An equivalent micro-bending stress can create, depending on the used wavelengths, a loss of attenuation 3 to 25 times greater when using G.652.D instead of G.657.A2 fibre.

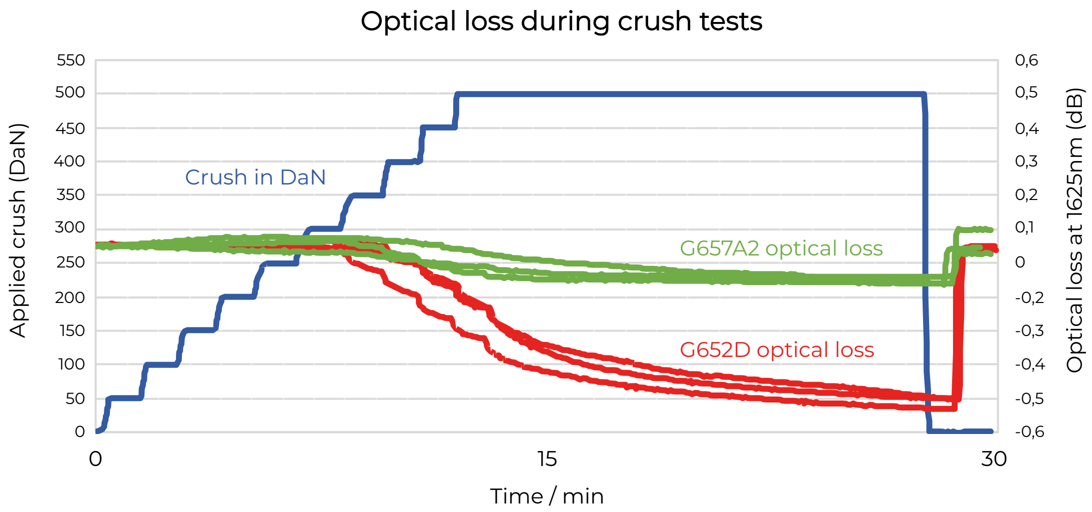
What about cable compression?

To measure the cable compression effects, a crush test was performed (according to IEC 60794-1-21 – method E3) on a cable containing different fibre types: G.657.A2 and G.652.D. The following graphic contains the outcome of this crush test and demonstrates that the attenuation is significantly different between G.657.A2 and G.652.D fibre in the same cable facing the same crush.
The blue curve represents the crush test force in daN over time.

Green curves shows the optical loss in dB on the G.657.A2 fibres, red curves on G.652.D fibres.

Compression on G.657.A2 fibres does not involve optical loss over 0.1 dB whereas G.652.D can present an optical loss over 0.5dB.

Note: both crush tests effects are reversible



This crush test raises the importance of the optical fibre type «fundamental choice». Other studies confirm this outcome. The impact of crush due to aerial anchor compression has also been studied. The effects of traction on an overhead cable moored to poles by anchoring clamps (appearance of micro-curvature phenomena at the mooring points), demonstrates once more the difference in the behaviour of the two types of optical fibres in the same cable. The signal attenuation with the same tensile force applied to the cable containing the two fibre types is less than 0.1dB for type G.657.A2 fibre and can reach 9dB for type G.652.D fibre.

Fibre type “fundamental choice” conclusion:

G.657.Ax fibre types show a better resilience to fibre and cable compression effects. Cable crush, cable compression in aerial anchor, cable sheath pinching and other “real life” events in distribution passive components as splices closure, streets cabinets can deteriorate the optical reliability of the network. In OFDN FttH network, several optical passive components are included, and they will face maintenance over long periods. G.657.Ax fibres compression resilience is a key parameter to assume optical fibre reliability of Optical Fibre Distribution Networks.

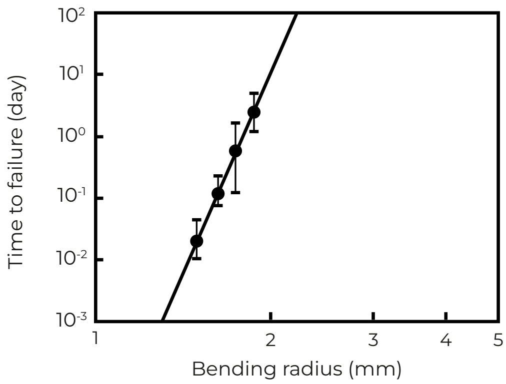
Mechanical reliability:

Insensitive fibre, yes! but not too much...

The benefits to using a fibre which is insensitive to curvature was explained, but it must be kept in mind that a fibre that would be «too insensitive», could also be a risky choice. Indeed, some constraints may be invisible during network validation tests carried out after the installation of the cable and the implementation of network components.

A stress can then escape the controls, while strongly impacting the service life of the optical fibre. In splice trays and coiling systems, for example, the attenuation associated with a strong curvature (macro-bending) of the optical fibre may go unnoticed or be confused with the attenuation associated with a splice or pigtail. If the radius of curvature is too small, it causes premature aging of the fibre and it may increase the breakage probability to short or medium terms (from a few days to a few months).

A «too insensitive» fibre is therefore not mechanically reliable. Curvature radii less than 4 mm strongly affect the service life of the optical fibres. In this highly sensitive area (very low bending radii), a difference of bending radius about one millimetre can divide the service life of the optical fibre by at least a factor of ten.
For example, at 3 mm radius of curvature, the fibre will have an estimated lifetime of a few hundred days while at 2 mm radius of curvature, its lifetime is estimated to be between 1 and 10 days.
(For more information refer to IEC TR 62 048 and ITU G series G59).



Insensitive fibre and mechanical reliability :
To allow the detection of bends impacting the service life of the optical fibre, G.657.Ax fibres which are sufficiently sensitive to bending radii lower than 7.5mm are recommended. The bending radii, impacting the service life of the fibre, are detectable and maintenance is possible before the optical fibre breaks or ages prematurely.

RECOMMENDED BY EUROPACABLE

Fibre elongation – The ultimate issue !

During its lifetime, cable faces strains which affect the optical fibre elongation:
- permanent or long term tensile stress: the cable is in constant tension due to its installation, temperature variations, its own weight (aerial cables for example).
- short-term tensil stress due to installation (pulling…) or during climatic overload on aerial cables (wind, ice…).

These tensile stresses will generate fibre elongation which are the major concern of the optical cable engineering. The design of an optical fibre cable is guided by the absolute necessity to limit the fibre elongation as it directly impact the mechanical reliability.
The chart hereunder demonstrates the impact of fibre elongation on its failure rate for a 25-year lifetime.

To reach a mechanical optical fibre reliability of more than 25 years, the permanent elongation of the fibre should remain in green or blue area. The fibre elongation in orange and red area could only occur for short term stress.

IEC 62048-TR	**144 OF - 10Km deployment**			
Fibre Elongation	≤ 0.10%	0.10%<FE≤0.30%	0.30%<FE≤0.50%	0.50%<FE≤0.60%
Failure rate at permanent elongation	25 years <0	25 years <1/100 fibre broken	25 years 1/15 fibre broken	25 years <1/2 fibre broken

Probability of fibre breakage as a function of the fibre elongation. IEC TR 62 048 outcomes

To conclude:

G.657.Ax fibres, called «bend insensitive», significantly improve the reliability of the optical transmission and the robustness of the optical network. Their use in high quality cables is highly recommended, particularly in FttH, Optical Fibre Distribution Networks.

In addition, the fibre elongation should be in line with the table above and using high quality cables will guarantee that the fibre elongation remains in the green or blue area for long term stress and in orange or red area for very short-term stress, as long as the cable manufacturer installation and environment of use recommendations are met.

To help determine the correct fibre elongation, a cable datasheet should specify at which fibre elongation the Maximum allowable tensile stress and Maximum operating tensile stress is applicable.

For more information, refer to Europacable technical newsletter « Understanding an optical fibre cable datacheet »

For further information please contact:
Alberto Lampasona, Director Public Affairs, a.lampasona@europacable.eu

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